

REM – Rapid Eye Mount. A fast slewing robotized infrared telescope

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Abstract. The main goal of the REM project is the observation of prompt afterglow of Gamma-Ray Burst (GRB) events. Such observations at Near InfraRed (NIR) wavelengths are even very promising, since they allow to monitor high- z Ly- α absorbed bursts as well as events occurring in dusty star-forming regions. In addition to GRB science, a large amount of time ($\sim 40\%$) will be available for different scientific targets: among these the study of variability of stellar objects open exciting new perspectives.

1. Introduction

In the last decade, mainly due to the observations by *BeppoSAX* and related optical Earth-based follow up, the physics of GRBs and their afterglow started to be understood. However, the intrinsic duration of the observational process, mainly due to the use of device non-optimized for fast response, did not allow up to now to monitor the prompt afterglow, i.e. the emission in the few seconds after the burst (except in one case, GRB 990123). In the next few years, dedicated missions such as HETEII or Swift and of other space-borne high-energy observatories with trigger capabilities (INTEGRAL, AGILE, etc.) will allow in a few years to accumulate a statistical significant number of GRB detections.

In this context, REM will be operational at the European Southern Observatory of La Silla within October 2002. REM shares with other telescopes the characteristics of fast pointing and full robotisation but it has the unique feature to be equipped with a high throughput NIR Camera. Any possible optimization of the trigger sources will leave some time in which REM can not observe any GRB afterglow due to latitude/longitude constraint. We estimate such *Idle Time* to be of the order of 40% of REM observing time. During the idle time REM will be used for multifrequency monitoring of variable objects. Three *Key programmes* have been identified by the REM science team as particularly suitable for REM: **a)** monitoring of Blazars, **b)** monitoring of flare and variable stars and **c)** observation of IR counterpart of galactic Black Hole (BH) candidates.

2. REM telescope and instrumentation

REM has a classical Ritchey–Chretien optical scheme mounted in an alt–azimuthal configuration with two Nasmyth focal stations, a 60 cm primary mirror and a total focal ratio of F/8. Such optical figures allow a compact structure that provides the needed stiffness for fast motion and windy environmental conditions such as those expected in a fully deployable dome at the La Silla observatory.

One of the Nasmyth focal station will be equipped with a fully cryogenic NIR ($0.9 - 2.3 \mu m$) camera. The camera design had been developed with high throughput as major goal. The camera has a focal reducer scheme and is made of two detached doublets of Silica and CaF_2 and further Silica correction lens. The pupil of the system is re–formed between the doublets allowing to locate a Lyot cold stop, imaging filters and grisms for low–resolution slit–less spectroscopy. The camera has quasi diffraction–limited Optical Quality. The dithering, needed for IR image processing is obtained via a wobbling wedge that shifts the image of about 20 pixels in any radial direction from the array center (Conconi et al. 2001).

The camera will be equipped with a 512x512 Rockwell HAWAII LPE HgCdTe chip ($18 \mu m$ pitch) with a peak efficiency of 64% and values never lower than 56% between 1 and $2.5 \mu m$. The camera (telescope and filter excluded) is expected to have a transmission of $T > 53\%$. With a scale of 1.16 arcsec/pixel the camera covers a FOV of $9.8 \times 9.8 \text{ arcmin}^2$. According to simulations such an high throughput allows to reach the limit magnitudes reported in Table 1.

Table 1. Limit Magnitudes for different S/N and integration time as computed via the REM telescope simulator.

T int.	Z S/N=10	Z S/N=5	J S/N=10	J S/N=5	H S/N=10	H S/N=5	K S/N=10	K S/N=5
5 sec	17.0	17.7	15.7	16.5	14.5	15.3	13.2	14.0
30 sec	19.9	20.7	16.6	17.4	15.5	16.2	14.2	14.9
600 sec	24.5	25.3	17.6	18.3	16.7	17.4	15.5	16.3

3. Observation of stellar objects

In its essence the REM telescope is a very efficient simultaneous ZJHK photometric device. The plate–scale chosen makes this telescope of limited use for extended objects or crowded fields but it certainly allow to collect photometry of point–like source and is therefore ideal to observe stellar objects in and outside our galaxy.

During the observation of a GRB REM will acquire continuously frames measuring NIR colors of all the stellar objects contained in such a frame. Among this object, any variability with time–scale smaller or comparable with the time in which REM will insist on the field will be detected. This will allows to discard variable objects from the list of stars to be used for calibration but it will also allow to discover new variables. Moreover also the colors of the constant stars will be measured with very high precision.

It is however during the idle time when REM will be a unique opportunity for many programs of paramount interest for various branches of stellar astrophysics. Indeed the expected limiting magnitudes of the REM instrument will easily allow to measure a plethora of classes of known variable stars with previously un-conceivable efficiency and precision.

In the following section we present a non-exhaustive description of some of the main fields in stellar astrophysics that have given proof in the recent past to gain a lot from good quality observations in the NIR.

3.1. Cepheids and RR Lyrae stars

Cepheids and RR Lyrae pulsating variables are known to have paramount astrophysical importance related to their use as distance and age indicators at the cosmological level. Such an importance is of course enhanced if we observe at IR wavelengths since the interstellar absorption in the K-band is about ten times smaller than the one in the V-band.

A great gain is also attainable by observing Cepheids and RR Lyrae at NIR wavelength due to the different view of the pulsation given at these and at optical wavelengths. This because the light variation depends both on the radius variation and the surface brightness (or effective temperature) variation but with different weight depending on the wavelength. Another advantage in IR observation of Cepheids regards the blanketing. In the 1–3 μm region, where the density of metallic absorption lines is low, this effect is much reduced.

The expected performances of the REM telescope allow the observation of the largest number of known Cepheids and RR Lyrae stars ever observed systematically in Z, J, H and K so far. Very bright Cepheids will be within the limiting magnitude of the REM instrument even in nearby galaxies. Beside gaining a new insight in the pulsation mechanisms ongoing in these stars we will then have the opportunity to put a further constraint to major distance and age calibrations via the application of independent methods based solely on IR measurements.

3.2. T–Tauri stars

T–Tauri stars are low-mass pre–ZAMS stars that were first distinguished due to their photometric variations. Monitoring of the variability of T–Tauri stars at visible and NIR wavelength suggested several causes for such variability derived basically from a picture of the circumstellar environment in which surrounding material in an infalling envelope (e.g. Calvet et al 1994) falls onto and dissipates angular momentum in a circumstellar disk. The presence of magnetic fields produce cool sun–like spots on the surface of the star but also channel the disk material on to the stellar surface producing hot isolated spots (Shu et al 1994).

In the above framework the variability of T–Tauri stars has multiple causes and various characteristics. The cool starspots modulate periodically the brightness of the star with amplitude slowly changing in time–scales of months or years as the spots evolve. Typical life–time of these spots is of the order of days or weeks.

On top of these some environmental characteristics such as the changes in extinction as infalling or orbiting material intersects the line–of–sight, can cause variability. Extinction variations can have amplitudes limited only by the

optical depth of the interceding material. The duration of the event depends on the size of the cloud and its velocity. Such clouds may either originate in the circumstellar environment or represent pristine infalling material.

Since the typical amplitude of variation of these stars is between some tenth to some magnitudes REM represents a valid tool to monitor these stars in ZJHK with good coverage and S/N ratio: most of the above described time-scales of variation are as well compatible with REM observing strategy.

3.3. Magnetic activity in late-type stars

In addition to cool spots, intense flares are the most remarkable manifestation of stellar magnetic activity. Flare events occur in the atmospheres of several type of stars, from pre-MS to post-MS cool stars and involve the whole atmosphere, from the photosphere up to the corona. Due to the rather different physical characteristics of these different layers, with temperatures and densities spanning over several decades, flare flux affects a wide range of wavelengths, from microwaves to X-rays, and possibly Gamma-Rays. Stellar flares are quite fast with typical time scales of flux increase to the maximum of the order of 10–100 s and decreases to the pre-flare level on times 10–100 longer (see Rodonó 1990): a striking case of a multi-wavelength phenomenon that, owing to its fast development, requires really simultaneous observations.

Multi-wavelength studies (see e.g., Rodonó et al. 1989) have shown that on the occasion of intense flares in the microwave, UV and optical wavebands, the IR flux decreases. Such negative flares are predicted by a non-thermal model based on inverse Compton effects by fast electron (Gurzadian 1980) and a thermal model based on the increased opacity of the H^- ion (Grinin 1976). The missing energy in the K band alone can account for the energy flux increase at all other wavelengths. Multi-wavelength monitoring of stellar flares are therefore relevant for the interpretation of magnetic phenomena.

The possibility of GRBs associated with stellar flares has been predicted, among others, by Becker and Morrison (1974), but no observations have been devoted to this aspect. Outside of the time devoted to the principal research objective, namely the GRB afterglow observations in IR, we intend to use the REM telescope to study negative flares in IR, as well as to ascertain whether any of the GRB detected by Swift is associated with a stellar flare rather than to an extragalactic phenomenon.

Finally, huge flux excess in the far IR have been detected on quiescent dMe active stars with ISO (Rodonó et al. 1999, Leto et al. 2001) and it will be interesting to relate those enhanced IR emissions with REM data.

3.4. Cataclysmic Variables, Low and High Mass X-Ray Binaries

Cataclysmic Variables (CVs) are semi-detached binary systems made up of a White Dwarf (WD) primary and a Main Sequence (MS) secondary. Material donated by the secondary star is funneled through the L1 Lagrangian point.

The NIR emission in CVs is produced by a variety of components: **1)** the accretion disk in non-magnetic systems or the accretion stream in magnetic systems, **2)** the accretion region near the surface of the WD, **3)** the accretion disk hot spot and **4)** the secondary star. Therefore, even photometrically, the NIR wavelengths offer a plethora of information about the component stars and

the accretion process within CVs. Indeed the classical approach to constraint SED (Spectral Energy Distribution) models for CVs is to disentangle within time-resolved NIR-Curves each component of the emission.

By browsing the catalogue of Cataclysmic variable by Ritter and Kolb (1998) we find a consistent number of CVs with V magnitude between 10 and 15. Very little is known about the infrared colours of these stars. However a number of these objects have been observed in these band providing evidence of K band flux larger than V band flux. The typical amplitude of variations in the NIR-curves is of the order of $0^m.3$, well within the expected capabilities of the REM telescope.

Low Mass X-Ray Binaries (LMXBs) containing either a neutron star or a black hole, accrete matter from the late-type companion by means of an accretion disk. LMXBs can be divided into subclasses according to their location in the Galaxy: bright Galactic Bulge Sources located near the Galactic Center and the other LMXBs in the Galactic disk. The study of the first subclass has been severely hampered by the heavy obscuration, which made even the recognition of the optical counterpart difficult. The dichotomy between these two LMXB subclasses is poorly understood. The IR band provides us with an ideal window for observing these systems. REM observation can help studying the variability of these objects in connection with their X-ray fluxes.

Infrared monitoring of High mass X-ray Binaries (HMXBs) is especially important in the case of Be companion stars. These systems are usually transient: large X-ray outbursts are associated to shell ejection episodes whereas smaller ones with passages of the neutron star companion near periastron. IR monitoring therefore provides a unique opportunity to test the environment in which the neutron star is accreting (Negueruela 1998). IR monitoring of these sources, which are usually bright and variable (up to two magnitudes), in conjunction with X-ray monitoring can shed light on the outburst onset mechanism (e.g. propeller vs. direct accretion) as well as lead to the prediction for the occurrence of X-ray outbursts which could then be monitored much more accurately, with pointing X-ray instruments.

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